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A MODEL FOR STUDENT ACHIEVEMENT.

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DESCRIPTORS- #ACHIEVEMENT, SOCIOECONOMIC STATUS, FAMILY STRUCTURE, ETHNIC STATUS, RESEARCH, #JUNIOR HIGH SCHOOL STUDENTS, EDUCATIONAL OPPORTUNITIES, SURVEYS,

THE MAIN GOAL OF THIS ANALYSIS WAS TO REDUCE THE DATA OBTAINED FROM THE EDUCATIONAL OPPORTUNITIES SURVEY INTO MEANINGFUL INDICES AND SETS OF INDICES THAT COULD BE USED IN FUTURE ANALYSES OF THE EDUCATIONAL SYSTEM. AFTER ESTIMATING FOR MISSING DATA, INTERCORRELATIONS OF THE STUDENT, TEACHER, AND PRINCIPAL SETS OF VARIABLES WERE COMPUTED AND THEN SUBJECTED TO A SERIES OF FACTOR ANALYSES. THE OBJECTIVE OF THESE ANALYSES WAS TO OBTAIN MEANINGFUL GROUPINGS OF VARIABLES. FROM THESE, INDEX SCORES WERE CALCULATED. USING THESE INDICES, THE FACTORS THAT CONTRIBUTE TO ACHIEVEMENT AMONG NINTH-GRADERS IN 932 SCHOOLS WERE ANALYZED. MULTIPLE CORRELATIONS, MULTIPLE REGRESSION EQUATIONS, AND A COMMONALITY FORMULA WERE USED IN COMPARING THE DEPENDENT VARIABLES WITH THE VARIABLES OF SOCIO-ECONOMIC STATUS, FAMILY-STRUCTURE AND STABILITY, AND THE RACIAL-ETHNIC COMPOSITION. THE ANALYSES SHOWED THAT THESE THREE VARIABLES BEAR AN IMPORTANT RELATIONSHIP TO ACHIEVEMENT. (CG)

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# NATIONAL CENTER FOR EDUCATIONAL STATISTICS
## Division of Operations Analysis

## A MODEL FOR STUDENT ACHIEVEMENT

by

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# A Model For Student Achievement *

## Introduction

The Division of Operations Analysis of the U.S. Office of Education is engaged in a continuing effort to develop models of various aspects of the educational system. One major effort with which I have had the pleasure to be associated, is the development of models of student achievement. It is intended that these models would be useful in providing guidelines for existing programs or indicate where new programs might be useful.

## Data Base

We have been working with a number of data bases but most of our work has utilized a body of data obtained from the Educational Opportunities Survey. This survey entailed the testing and surveying of about 650,000 students in some 4,000 public schools throughout the country in grades 1, 3, 6, 9, and 12 together with their teachers, principals and superintendents. The Survey sample consisted of a 5 percent sample of schools. The data base is comprehensive in that detailed factual and attitudinal information was collected on the students' home background, attitude towards school, race relations and the world. A battery of ability and achievement tests was administered at each grade level. Information was collected from the teachers and principals concerning their training and experience, their view of the school, etc. The final part of the teacher questionnaire consisted of a 30 item contextual vocabulary test which was intended to be a measure of the verbal facility of the teacher. In addition, the principal provided data on the school's facilities, staff, programs, curricula, etc. A report investigating the Equality of Educational Opportunity for various racial and ethnic groups was presented to the Congress under the principal authorship of James S. Coleman. This report, which has become known as "The Coleman Report", contains detailed information on the design of the survey and I will refer you to that report for further details (Coleman et al, 1966).

I would like to dwell now on some of the things we have been trying to accomplish using this data base.

* The author is indebted to his many colleagues in the National Center for Educational Statistics for their helpful assistance through all phases of this study. This paper was presented at the U.S. Office of Education Symposium: Operations Analysis of Education, Washington, D.C., November 20-22, 1967.

## Research Strategy

### Estimation of Missing Data

The main goal of the analyses we have been doing was to reduce the more than 400 variables in an empirically meaningful way into indices and sets of indices, so that the volume of data processing and complexity of later analyses could be reduced. Thus it was hoped that the regression equations would be more sharply defined if things that seemed to go together both empirically and on the basis of their content were first grouped together so that what they had in common could make a more clear cut contribution. Earlier experience with these data showed that when each school facility such as a library or gymnasium was kept separate it might make a very small positive contribution to school achievement. It was also planned to conduct systematic or explanatory between school, within-school and total regressions for various combinations of variables. By explanatory regressions is meant that various combinations of subsets of variables would be entered into the regressions to see which sets would help to explain the predictable variance in achievement.

Before the variables could be reduced into meaningful groupings however, decisions had to be made concerning the estimation of missing data and the coding or scaling of variables. As a guide in the estimation of missing data or handling of non-responses, it was decided to analyze the responses to each question against one or more criteria or dependent variables so that not only the percent responding to each item or response alternative, but also their mean score on the dependent variable could be used as a guide in coding the variables and in assigning a value to the non-respondents.

Since the approach differed somewhat for the student, teacher and principal questionnaires each analysis will be described separately. The various steps that we went through are given in Table 1.

A factor analysis was conducted on the intercorrelations of the five ninth grade achievement measures. These measures were: General Information, Reading Comprehension, Verbal Ability, Mathematics Achievement and Non-Verbal Ability. The factor analysis showed that a single factor could be used to describe the intercorrelations of these achievement measures (Mayeske and Weinfeld, Technical Note Number 21). Accordingly, the weights from the first principal component of the intercorrelations were used to weight scores on the individual tests and sum them to obtain an overall achievement composite. It was this achievement composite which was used as a criterion against which item responses were analyzed. This achievement composite is also the dependent variable for many later analyses.

TABLE 1

Sequence of Steps Entailed in Data Analysis and Reduction

| Student Variables | School Variables | |
|---|---|---|
| | Teacher Variables | Principal Variables |
| Develop Achievement Composite | | |
| Analyze variables against achievement composite scores | Analyze variables against teacher's verbal score | Analyze variables against school size, rural-urban and socio-economic status, and principal's salary |
| Criterion scale variables | Scale variables | Scale variables |
| Correlate variables and factor analyze for indices | Correlate variables and factor analyze for indices | Correlate variables and factor analyze for indices |
| Calculate index scores | Calculate index scores | Calculate index scores |
| Combine indices and perform regressions | | |

In order to maximize the linear relationship of each student variable with student achievement, criterion scaling was employed. By criterion scaling is meant that each item response was coded or scaled by assigning the mean value of the dependent variable for each of the different response alternatives for an item. Table 2 shows the criterion scale analysis for the categorical variable of "Father's Occupation." The reader will note the percent of 9th grade students responding to each item alternative and their mean score on the achievement composite, where the total responses for each item have been set to a mean of 50 and a standard deviation of 10. When the mean value of the dependent variable is assigned as the code or scale value for each item alternative the items or variables are said to be criterion scaled. Almost all of the 9th grade student variables were coded in this manner (Weinfeld et al, Unpublished Manuscript Number 60).

For the teacher variables, each item was analyzed against the teacher's total score on a self-administered contextual vocabulary test (Mayeske et al, Technical Note Number 32). For the principal variables each item was analyzed against the number of students enrolled in the school, the rural-urban and socio-economic status of the school, and the principal's salary (Mayeske et al, Unpublished Manuscript Number 61). These analyses were used as guides in assigning codes or scale values and in estimating missing data. However, for the teacher's and principal's questionnaires the items were not coded so as to maximize their relationship with these dependent or criterion variables.

Reduction of Variables

The intercorrelations of the student, teacher and principal sets of variables were each subjected to a series of factor analyses. The objective of these analyses was to obtain meaningful groupings of variables. To accomplish this objective a large number of subsets of the variables were each subjected to Principal Components analyses and Varimax rotations (Horst, 1965). The Principal Component method has the desirable property that it extracts the roots and associated factors in descending order of magnitude. Hence the first root is the largest, the second root the next largest, etc. Factors with a root of one or greater were subjected to a Varimax rotation. This is a technique for rotating the principal factors into a position that may be meaningful. It attempts to maximize the high and low weights for a factor so that the variables that have high weights on a factor can be thought of as belonging together and an interpretive label might be applied to what they have in common.

This approach was essentially iterative in that variables that did not form meaningful groupings or blurred an otherwise meaningful grouping were eliminated and the remaining variables were refactored. The teacher and student variables readily fell into meaningful groupings after two iterations which resulted in the elimination of about six to twelve vari-

TABLE 2.-Percent of 9th Grade Students and Their Average Composite Achievement Score Classified by Father's Occupation

| CATEGORY | FATHER'S OCCUPATION | PERCENT | COMPOSITE MEAN* | COMPOSITE STD. DEV. |
|---|---|---|---|---|
| 1 | Technical | 2.8 | 52.674 | 10.328 |
| 2 | Official | 4.1 | 52.299 | 10.226 |
| 3 | Manager | 12.6 | 53.451 | 9.160 |
| 4 | Semi-skilled | 16.6 | 50.060 | 9.119 |
| 5 | Salesman | 4.3 | 53.877 | 8.898 |
| 6 | Farm or ranch manager or owner | 3.8 | 50.397 | 10.250 |
| 7 | Farm worker | 2.4 | 43.316 | 9.405 |
| 8 | Workman or laborer | 10.5 | 48.657 | 8.897 |
| 9 | Professional | 6.7 | 56.597 | 9.368 |
| 10 | Skilled worker or foreman | 20.1 | 51.000 | 8.779 |
| 11 | Don't know | 10.8 | 43.057 | 8.847 |
| 0 | Non-response | 5.2 | 42.599 | 10.365 |
| | TOTAL | 100.00** | 50.000 | 10.000 |

*When the mean value is assigned as the code for that alternative the variable is said to be criterion scaled.

**Based on 133,136 ninth grade students.

ables from each set. The highest weights from the Varimax rotation were used to multiply the variables by to obtain index scores. In order to keep the index score intercorrelations low a variable was allowed to have a weight on only one index.

The variables from the principal questionnaire dealt with a wide variety of different aspects of the school. These variables did not readily fall into any naturally meaningful groups. Consequently, a priori groupings, such as variables concerned with the physical plant or instructional facilities were subjected to a Principal Component analysis. The weights from the first principal component were then used to obtain index scores for each school.

Description of Indices

Pages 7 through 9 give a brief description of the indices obtained and other variables retained for future analyses. A detailed description of the development of these indices is given in the list of references (see Mayeske et al, Unpublished Manuscripts of Correlational and Factorial Analyses).

When the full set of school variables is referred to later on, this reference will pertain to the combined set of teacher, principal and school indices and variables that are listed on pages 8 and 9.

Using these indices we are currently conducting systematic between-school, within-school and total analyses using correlational and regression techniques. In this paper I would like to focus on our most complete set of analyses. These analyses use ninth grade schools as the unit of analysis. Thus when we speak of Socio-Economic Status we are talking about the average of the socio-economic index scores for the ninth grade students in a particular school and when we speak of Achievement we are talking about the average achievement of the ninth grade students in a school. In a similar manner we are talking about the average Experience or Training of the teachers in the school. There were approximately 923 schools used in these analyses.

Discussion of Zero-Order Correlations

Although our primary interest was in factors that contribute to school achievement we felt that many of the other student indices such as: Expectations for Excellence, Attitude Toward Life, Educational Desires and Plans, and Study Habits could also be regarded as being influenced by the school. Consequently we included these indices as dependent variables in addition to the Achievement Composite.

## Student Indices

1. Expectations for Excellence - student believes that his mother, father and teacher want him to be a good student and he desires to be a good student,

2. Socio-Economic Status - defined by mother's and father's educational level, father's occupational level, rooms in the home, number of siblings, reading materials and appliances in the home and urbanness of background,

3. Attitude Toward Life - a student with a high score on this index believes that people like himself have a chance to be successful, when he tries to get ahead he won't experience many obstacles, hard work is more important than good luck for success, won't have a hard time getting a job with a good education, etc.,

4. Family Structure and Stability - a student with a high score has both his father and mother in the home, father is the major source of income, he hasn't changed schools recently, etc.,

5. Educational Desires and Plans - a student with a high score desires and plans to go to college, his parents want him to go to college and he has high occupational level aspirations,

6. Study Habits - a student with a high score spends about 2 hours a day studying, has frequent discussions about his school work with his parents, was read to as a child before he started school, read many books during the summer, etc.,

7. Racial-Ethnic Differences in Achievement - a variable created by assigning each student the average achievement score obtained by his racial or ethnic group.

## Teacher Indices

1. Experience - comprised of the teacher's age, years of teaching experience and years of teaching in his present school,

2. Teaching Conditions - comprised of various aspects of the teacher's view of his teaching situation such as how hard the students try to achieve, their academic ability, the reputation of the school and student disciplinary, racial, etc. problems,

3. Localism of Background - a teacher with a high score has spent most of his life in a small geographic area and has graduated from high school and college in that locale,

4. Socio-Economic Background - comprised of the teacher's parent's educational level, father's occupation and rural-urbanness of their background,

5. Training - comprised of the teacher's highest degree held, certification, salary level and tenure,

6. College Attended - comprised of the kind of undergraduate institution attended (eg. normal school, public or private university, etc.) the highest degree offered by that institution and the teacher's rating of the academic level of the institution,

7. Teaching Related Activities - comprised of the hours of unofficial time spent in preparation for class and counseling, the number of educational journals read regularly, etc.,

8. Preference for High Ability Students - teacher prefers to work with students of higher ability, socio-economic status, etc.,

9. Sex - scored high for a female, low for a male,

10. Racial-Ethnic Differences in Contextual Vocabulary - a variable created by assigning each teacher the average vocabulary score obtained by his racial or ethnic group,

11. Vocabulary Score - total number of items correct.

## Principal and School Indices

1. Principal's Experience - comprised of age, number of years experience as a principal, etc.,
2. Principal's Training - comprised of the highest degree held and salary level,
3. Principal's College Attended - same as teachers index,
4. Principal's Sex - a variable scored high for female, low for a male,
5. Plant and Physical Facilities - area of plant, possession of auditorium, gymnasium, etc.,
6. Instructional Facilities - special labs, shops, volumes in the library, etc.,
7. Specialized Staff and Services - art, music and remedial reading teachers, etc.,
8. Tracking - use of various kinds of ability grouping techniques,
9. Testing - frequency of different kinds of testing,
10. Transfers - number of students transferring in and out,
11. Remedial Programs - percent of students in remedial math and reading,
12. Free Milk and Lunch Programs - percent of students who get free milk and lunch,
13. Accreditation - whether or not school has state and regional accreditation,
14. Age of Texts - age of different texts used,
15. Availability of Texts - whether or not free texts are provided and if there is a sufficient number available,
16. Age of Building - a variable,
17. Pupils per room - a variable,
18. Pupils per teacher - a variable,
19. Number of students enrolled in the school,
20. School Reputation - the principal's estimate of the school's reputation.

In attempting to ascertain the influence of school variables on achievement one must first take into account or equate schools for differences in the kinds of students that they get initially. Thus if school A had children primarily from families where intellectual activities were not valued or pursued and school B had children from families where these activities were valued and pursued then one would expect the students in school B to have higher achievement levels than students in school A. These differences could be attributed to the influence of the different families rather than to the schools. Thus it would seem fitting and appropriate to equate schools for differences in the home background and racial-ethnic composition of their students before looking at the influence of school variables on achievement. By home background we will mean the student indices of Socio-Economic Status and Family Structure and Stability and for racial-ethnic composition we will use the student Racial-Ethnic difference variable.

Before we control for the combined effects of these variables using multiple regression techniques it may be instructive to look at the correlations of these variables with one another and with the dependent variables of interest. These are given in Table 3.

The reader will note in looking at the first three rows in Table 3 against column 8 which is the Achievement column, that at least one and usually more than one of the three variables that we are going to use to equate schools for differences in student inputs, are highly correlated with Achievement as well as with the other dependent variables. This suggests that after equating schools for these initial differences there may be very few differences among schools in achievement that could be related to other school variables. This reasoning is also supported by reading across row 9 in Table 3. This row contains the multiple correlation of the full set of 31 school variables with each of the other variables. This row shows that the school variables are moderately to highly correlated with each of the other variables.

Multiple Correlations

Table 4 shows the squared multiple correlations obtained when the dependent variables are regressed against the three control or equating variables of Socio-Economic Status, Family Structure and Stability and the Racial-Ethnic Composition of the student body. Looking across row 1 of that table we see that achievement is the most highly predictable of the dependent variables from the student body variables, having a squared multiple correlation of .82 or a multiple correlation of about .91. We might ask why school achievement should be so highly predictable using these three variables? One interpretation is that these results reflect the current social organization of our school systems. Thus schools are organized along residential lines and residental areas are in turn

TABLE 3

Intercorrelations of Independent and Dependent Variables

| | SES 1 | FSS 2 | REC 3 | EXP 4 | ATT 5 | ED PLN 6 | STDY 7 | ACH 8 |
|---|---|---|---|---|---|---|---|---|
| 1. Socio-Economic Status (SES) | 1.00 | .67 | .68 | .47 | .60 | .69 | .57 | .82 |
| 2. Family Structure and Stability (FSS) | .67 | 1.00 | .70 | .66 | .75 | .56 | .82 | .66 |
| 3. Racial-Ethnic Composition (REC) | .68 | .70 | 1.00 | .28 | .60 | .23 | .42 | .84 |
| 4. Expectations (EXP) | .47 | .66 | .28 | 1.00 | .72 | .69 | .82 | .31 |
| 5. Attitude Toward Life (ATT) | .60 | .75 | .60 | .72 | 1.00 | .62 | .79 | .64 |
| 6. Education Plans and Desires (ED PLN) | .69 | .56 | .28 | .69 | .62 | 1.00 | .68 | .50 |
| 7. Study Habits (STDY) | .57 | .82 | .42 | .82 | .79 | .68 | 1.00 | .46 |
| 8. Achievement (ACH) | .82 | .66 | .84 | .31 | .64 | .50 | .46 | 1.00 |
| 9. School Variables (full set of 31)* | .82 | .65 | .92 | .42 | .59 | .56 | .45 | .92 |

*This row contains the multiple correlation of the full set of school variables with each of the other variables.

TABLE 4

Squared Multiple Correlations of Dependent Variables Against Student Body Variables and School Variables

| Variable Set | Expectations | Attitude Toward Life | Educational Plans | Study Habits | Achievement |
|---|---|---|---|---|---|
| 1. Student Body | .5214 | .5847 | .6066 | .7373 | .8207 |
| 2. School | .1773 | .3500 | .3179 | .2023 | .7601 |
| 3. Student Body and School | .6309 | .6386 | .6679 | .7773 | .8662 |
| 4. (3) - (1) | .1095 | .0539 | .0613 | .0400 | .0455 |
| 5. (3) - (2) | .4536 | .2886 | .3500 | .5750 | .1061 |

organized along socio-economic and racial-ethnic lines. This line of thought is further supported by some of our analyses of individual students when they are not aggregated by schools. These analyses showed that individual student achievement was moderately predictable from the students' Socio-Economic Status, Family Structure, and Racial-Ethnic group membership (the multiple correlation being. .60) (Mayeske et al, Unpublished Manuscript Number 80). One can infer that some kind of a sorting process is going on whereby white students with higher achievement and socio-economic status go to schools with similar kinds of students which has the effect of making their aggregated school achievement more predictable than individual achievement.

If we are willing to grant that this sorting process takes place then what can we say about the effects of school variables in such a context? Row 2 of Table 4 shows the squared multiple correlations of the school variables with the dependent variables. It's clear from this table that all of the dependent variables are more predictable using the student body variables than using the school variables. By comparing the values in row 3 with their counterparts in row 1 we can get some idea of the additional

contribution of the school variables to the dependent variables, and by comparing the values in row 3 with their counterparts in row 2 we can get some idea of the additional contribution of the student body variables. These differences, often called the unique variance or contribution, are given in rows 4 and 5. Examination of the values in row 4 indicates that the relative contribution of the school variables after family background and racial composition have been controlled for, are small but positive for all the dependent variables. Examination of the values in row 5 indicates that the relative contribution of the student body variables after school variables have been controlled for are moderate to large except for Achievement.

Since the relative contributions of the school variables are small does it mean they are unimportant? Not necessarily, for as we showed earlier, the school variables tend to be bound up with the student body characteristics, and this is particularly so for Achievement. Might we then be able to develop an expression of this commonness or overlap? We are indebted to Dr. Alex Mood for developing a measure which will allow us to express this commonality.

Commonality: A definition of this measure of commonality is given below.

Let: C (B, S) stand for commonality or overlap of the student body variables (B) and the school variables (S)

$R^2$ (B) - the squared multiple correlation of the student body variables with the dependent variable

$R^2$ (S) - the squared multiple correlation of the school variables with the dependent variable

$R^2$ (B, S) - the squared multiple correlation of the student body and school variables with the dependent variable

U (B) = $R^2$ (B, S) - $R^2$ (S) - the unique contribution of the student body variables

U (S) = $R^2$ (B, S) - $R^2$ (B) - the unique contribution of the school variables

Then C (B, S) = $R^2$ (B, S) - U (B) - U (S) and $R^2$ (S) can be expressed as:

$$R^2 (S) = C (B, S) + U (S) \text{ and}$$

$$R^2 (B) = C (B, S) + U (B)$$

Table 5 gives the squared multiple correlations of the school variables with the dependent variables when they are expressed as a function of their unique contribution and their commonality coefficient with the student body variables.

TABLE 5

The Squared Multiple Correlations of the School Variables With the Dependent Variables Expressed as a Function of Their Unique Contribution and Their Commonality Coefficient With the Student Body Variables

| | $R^2$ (S) = C (B, S) + U (S) |
|---|---|
| Expectations | .1773 = .0678 + .1095 |
| Attitude Toward Life | .3500 = .2961 + .0539 |
| Educational Plans and Desires | .3179 = .2566 + .0613 |
| Study Habits | .2023 = .1623 + .0400 |
| Achievement | .7601 = .7146 + .0455 |

In looking at the list at Table 5 we note in the first column that achievement is the most predictable of the dependent variables from the school variables. Next, in descending order are, Attitude Toward Life, Educational Plans and Desires, Study Habits, and Expectations. When we look at the commonality coefficient C (B, S), we note that almost all of the variance in achievement predictable from school variables is bound up in the student body-school overlap. Although the level of predictability is lower this same trend holds for Attitude Toward Life, Educational Plans and Desires and Study Habits. The school has its greatest unique contribution for Expectations and less so for the other variables.

Table 6 gives the squared multiple correlations of the student body variables with the dependent variables when they are expressed as a function of their unique contribution and their commonality coefficient with the school variables.

TABLE 6

The Squared Multiple Correlations of the Student Body Variables With the Dependent Variables Expressed as a Function of Their Unique Contribution and Their Commonality Coefficient With the School Variables

| | $R^2$ (B) = C (B, S) + U (B) |
|---|---|
| Expectations | .5214 = .0678 + .4536 |
| Attitude Toward Life | .5847 = .2961 + .2886 |
| Educational Plans and Desires | .6066 = .2566 + .3500 |
| Study Habits | .7373 = .1623 + .5750 |
| Achievement | .8207 = .7146 + .1061 |

In looking at Table 6 we can note, again in the first column, that Achievement is the most predictable of the dependent variables from the student body variables. Next, in descending order are, Study Habits, Educational Plans and Desires, Attitude Toward Life and Expectations. The student body variables have their greatest unique contribution for Educational Plans and Desires and their smallest unique contribution for Achievement.

In view of the small unique contribution of the school variables does this mean that they are unimportant or have little influence? No, it does not. What it does indicate is that it is very difficult to specify just how influential these variables might be in bringing about student achievement.

In light of these considerations one might conclude that both the family background of the student and his school are important in promoting achievement. We might speculate for a moment on various avenues that might be fruitfully explored along these lines.

These analyses show that the family-home background constellation of Socio-Economic Status, Family Structure and Racial-Ethnic group membership bear an important relationship to achievement, the multiple correlation being .91 when students are aggregated by schools and .60 when they are not aggregated by schools. This suggests that where family involvement in the child's education is not present or is only weakly present, substantial gains in Achievement might be realized through a greater involvement of them in support of their child's education.

In considering the school as an avenue for promoting student achievement it may be instructive to see what school variables such as the facilities, special programs, teacher's training and experience, are related to achievement. When we inspect these individual correlations we are impressed by the low degree of relationship that exists. This indicates that small changes in just a few variables will not bring about substantial gains in achievement. Perhaps radical departures from existing practices will bring about these desired changes, at least we should give them a try.

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